A Personal History of the

Measurement of the Helicity of the Neutrino

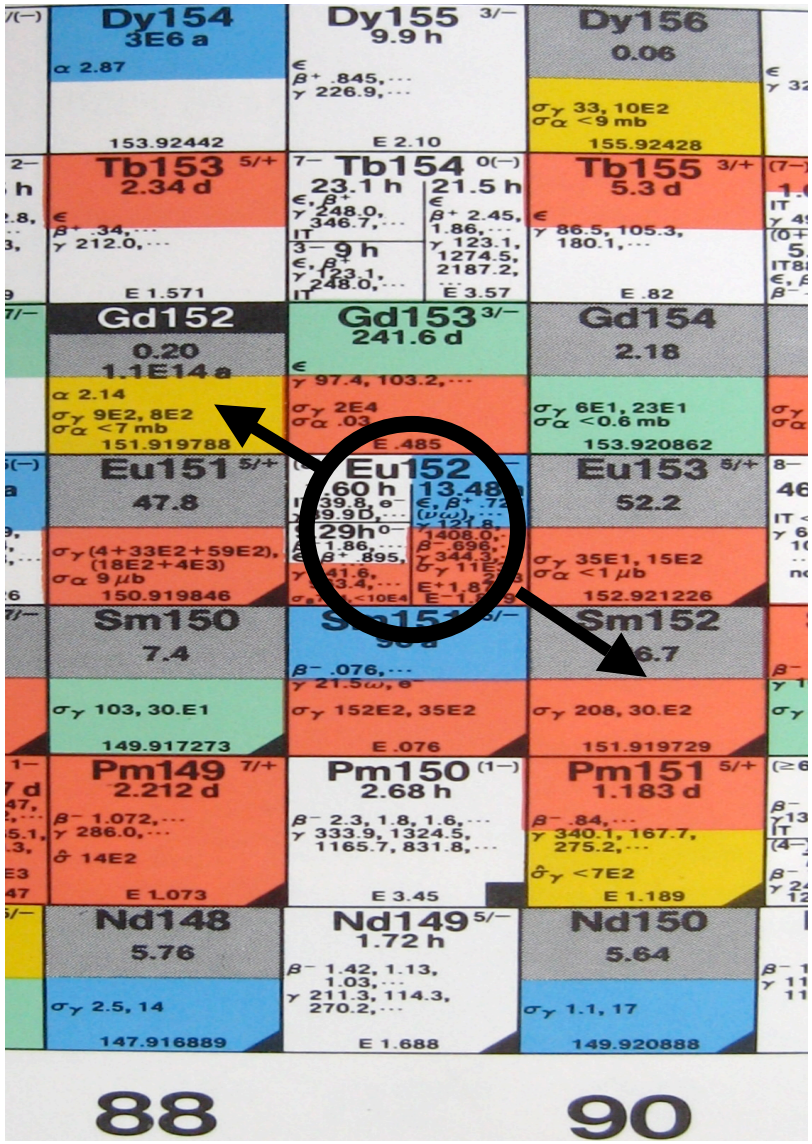
Lee Grodzins

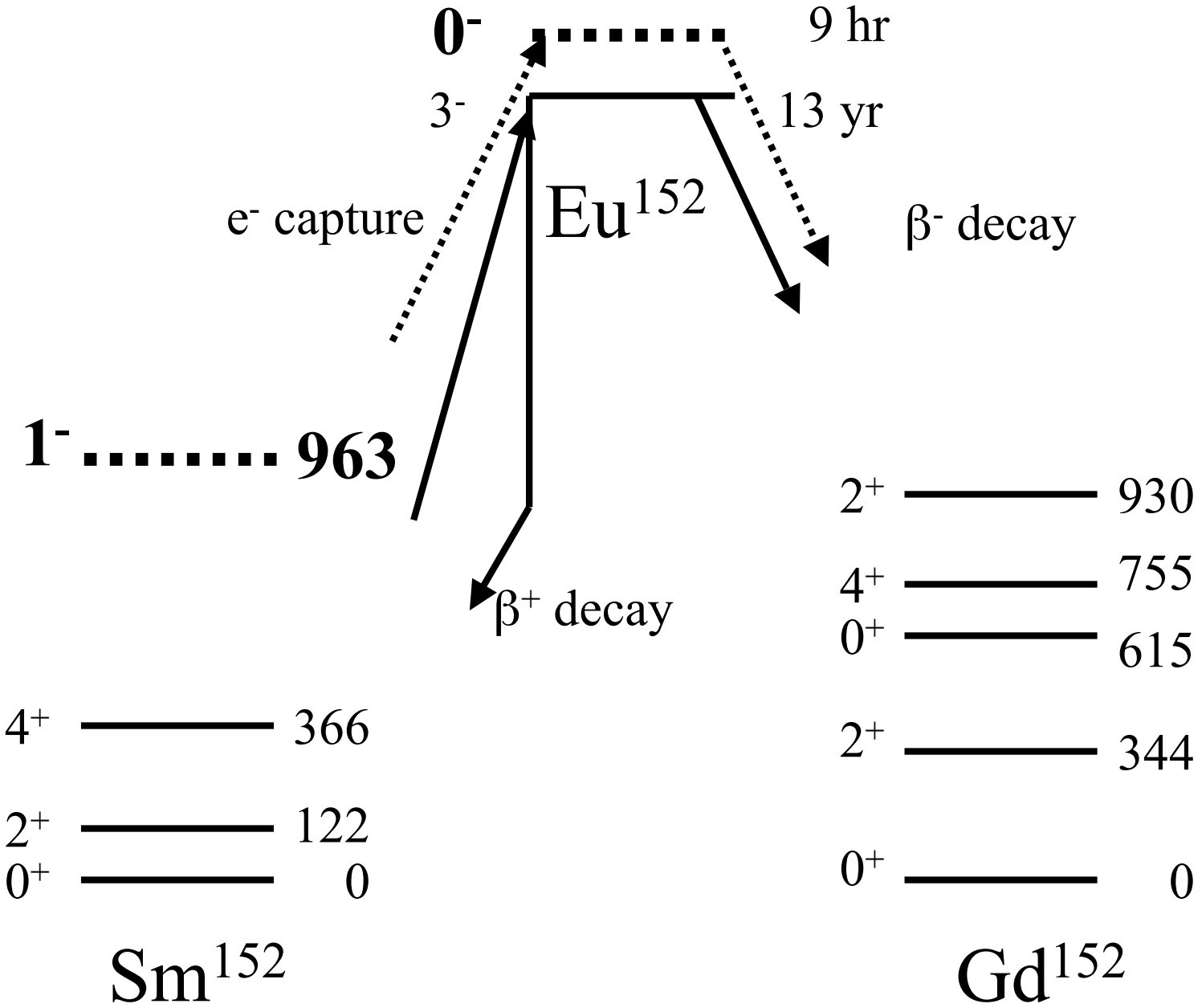
In appreciation of

Maurice Goldhaber

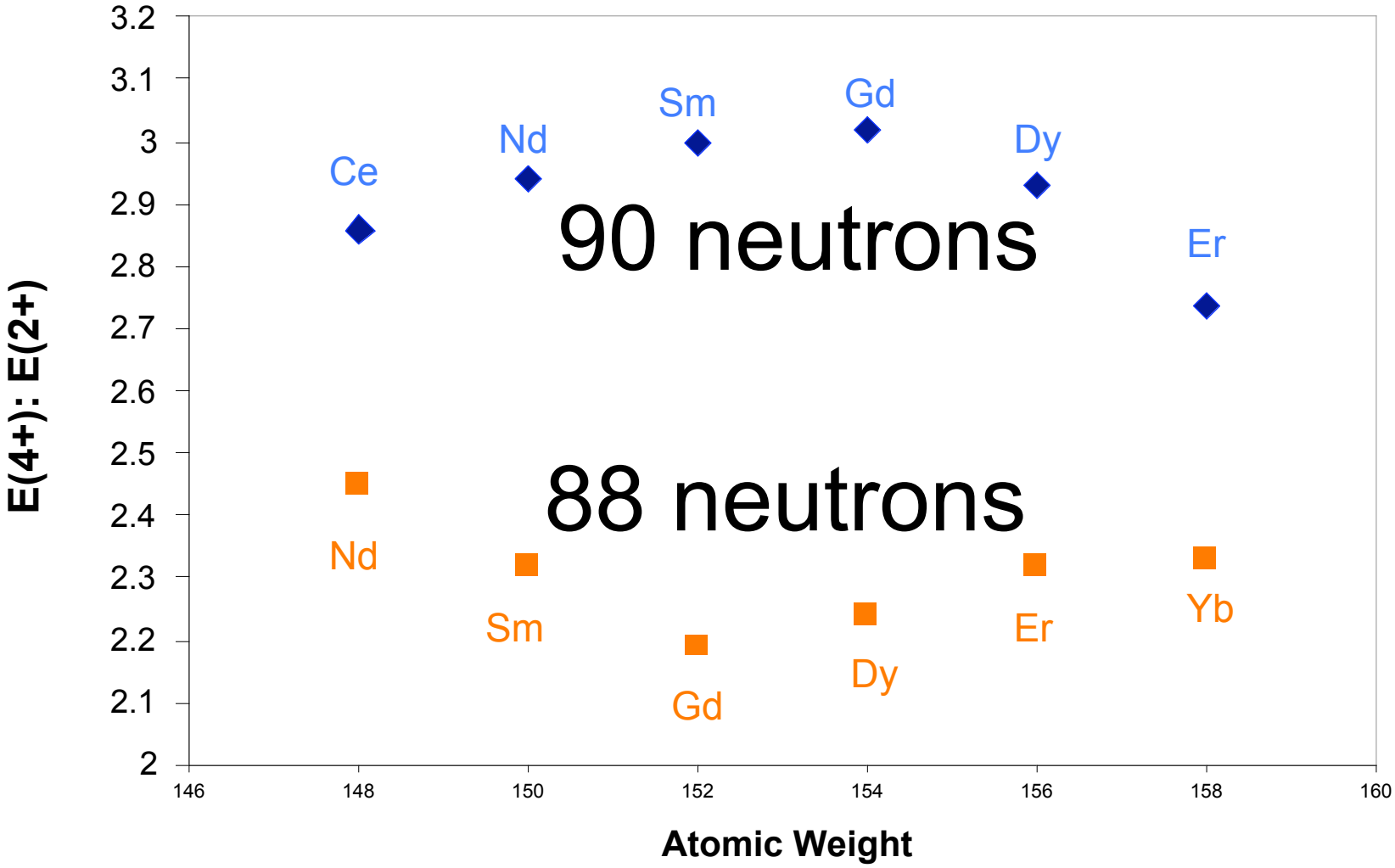
1955

Maurice's Suggestion




0-
9 hr
3-
13 yr
e- capture
Eu152
β- decay
1- 963
β+ decay
4+ 366
2+ 122
0+ 0
Sm152
2+ 930
4+ 755
0+ 615
2+ 344
0+ 0
Gd152

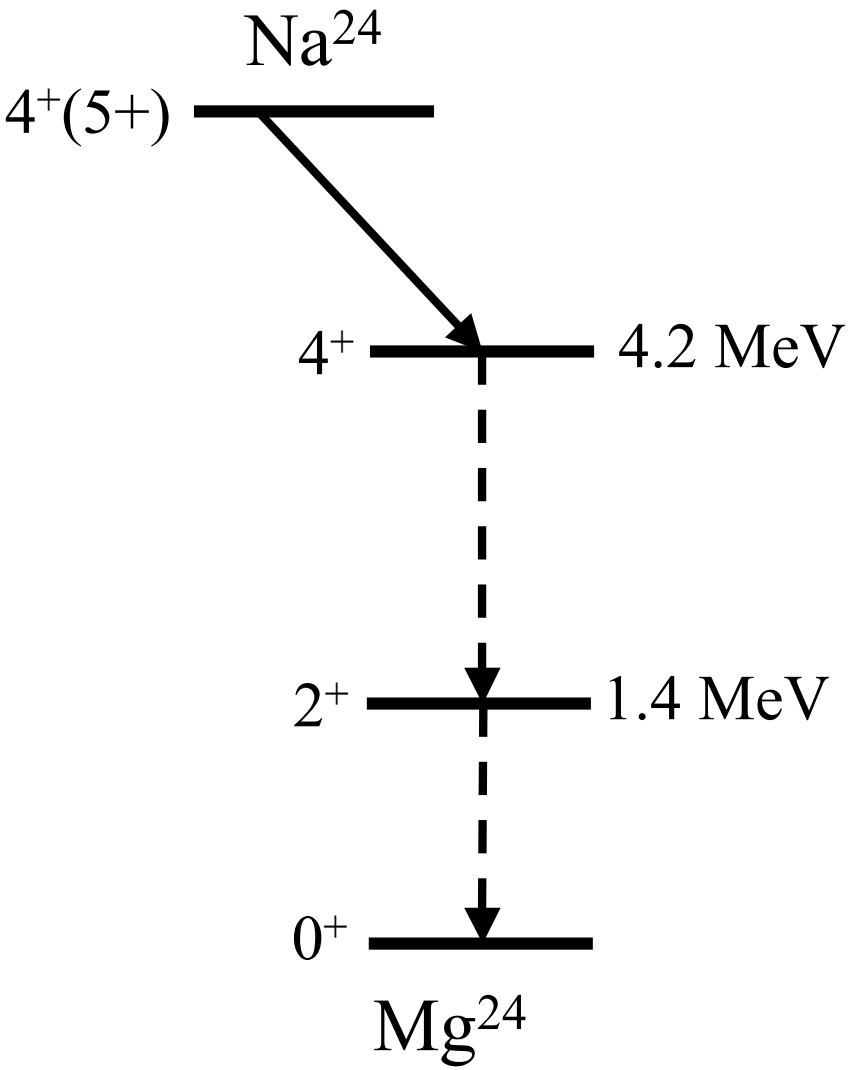
88 Neutrons: Vibrational Spectra
90 Neutrons: Rotational Spectra

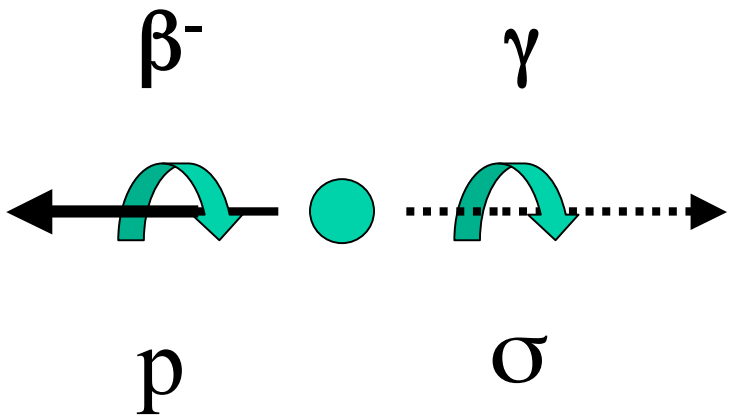


1956

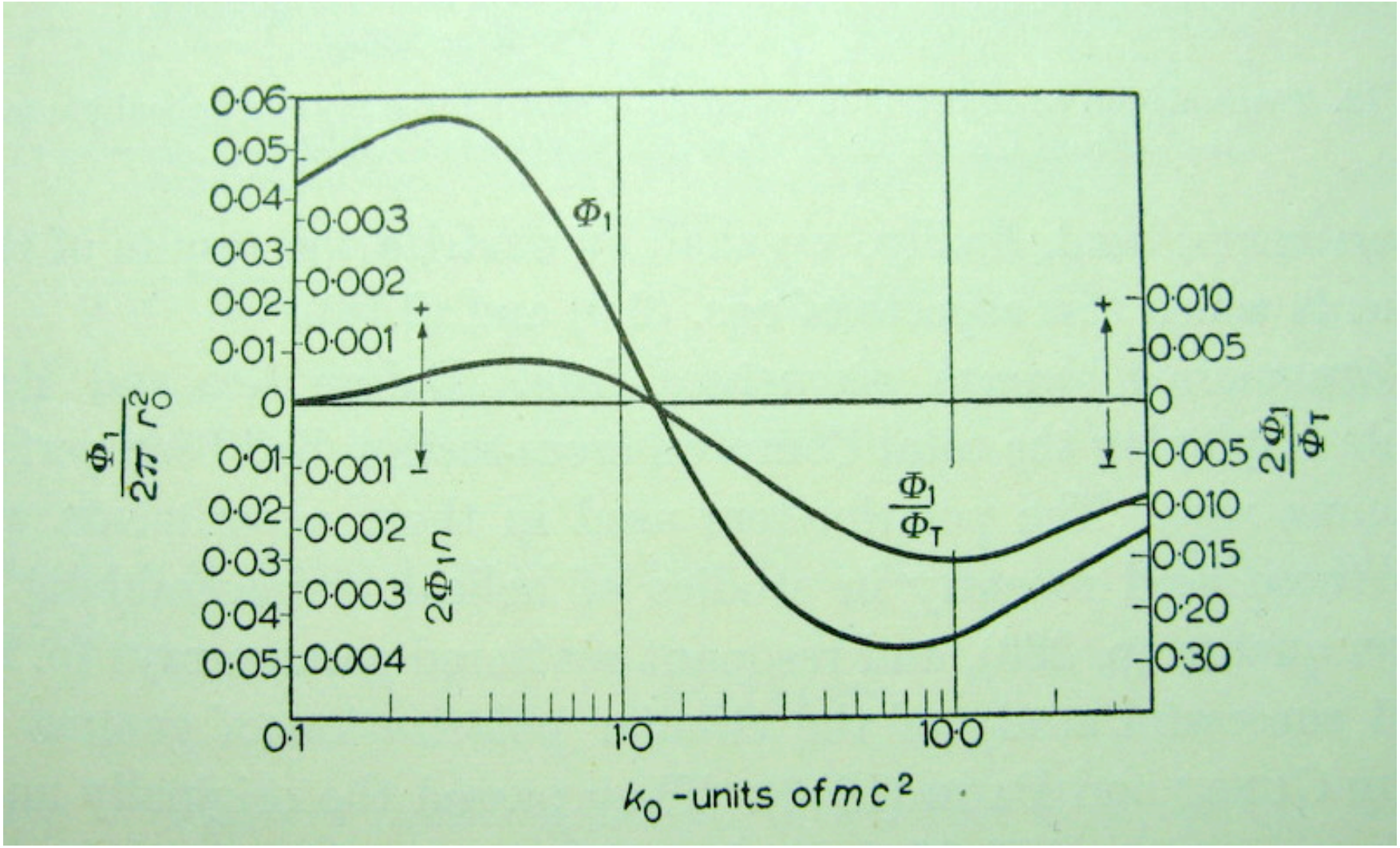
- **T. D. Lee and C.N. Yang at BNL**
- **Parity-violation paper**
- **Preprints circulate**
- **Sergio DeBenedetti proposes a test of parity violation not considered by Lee and Yang.**

Circular polarization of γ correlated with momentum of β



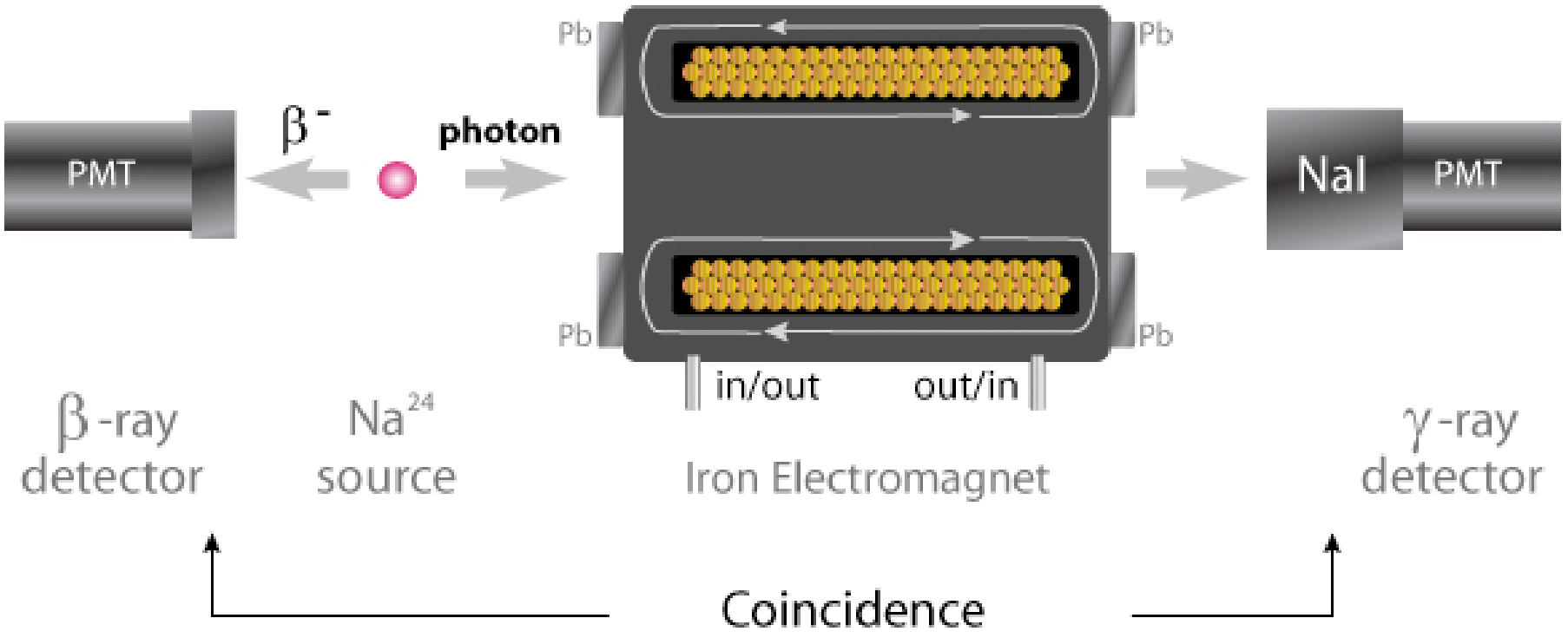


The Energy Dependence of the Polarimeter



Our First Parity Violation Experiment.

Sergio DeBenedetti, L.G., Richard Madey, A.S.

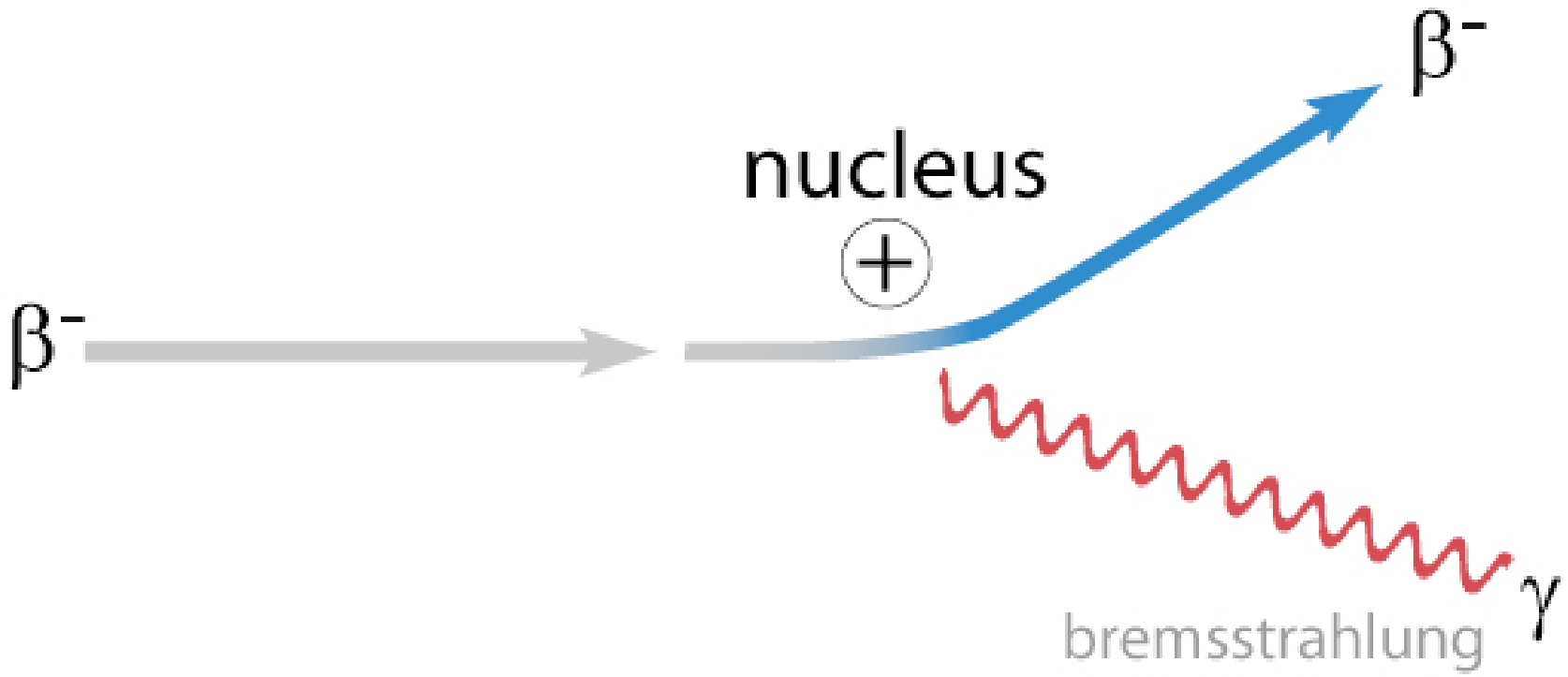


- **0.4% effect was correctly measured,**
- **Two small to be convincing.**
- **Never Published.**
- **December: C.S. Wu, Ambler et al.**

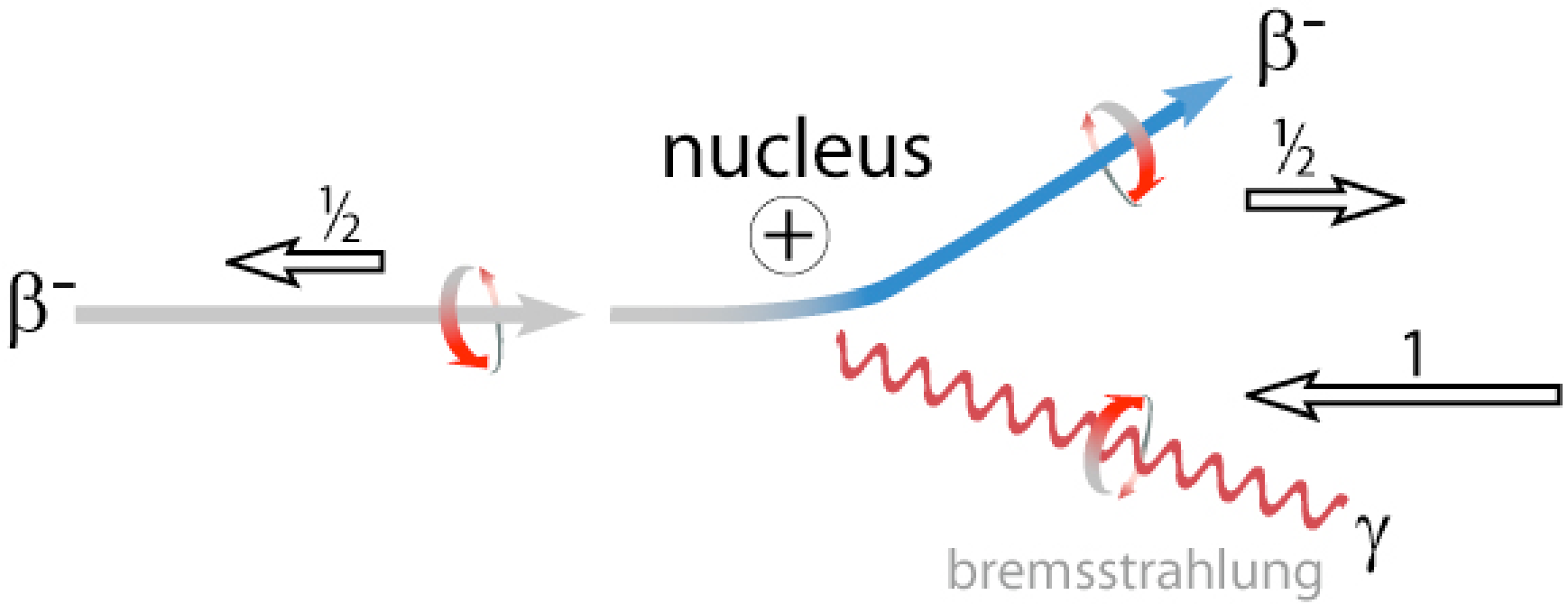
1957

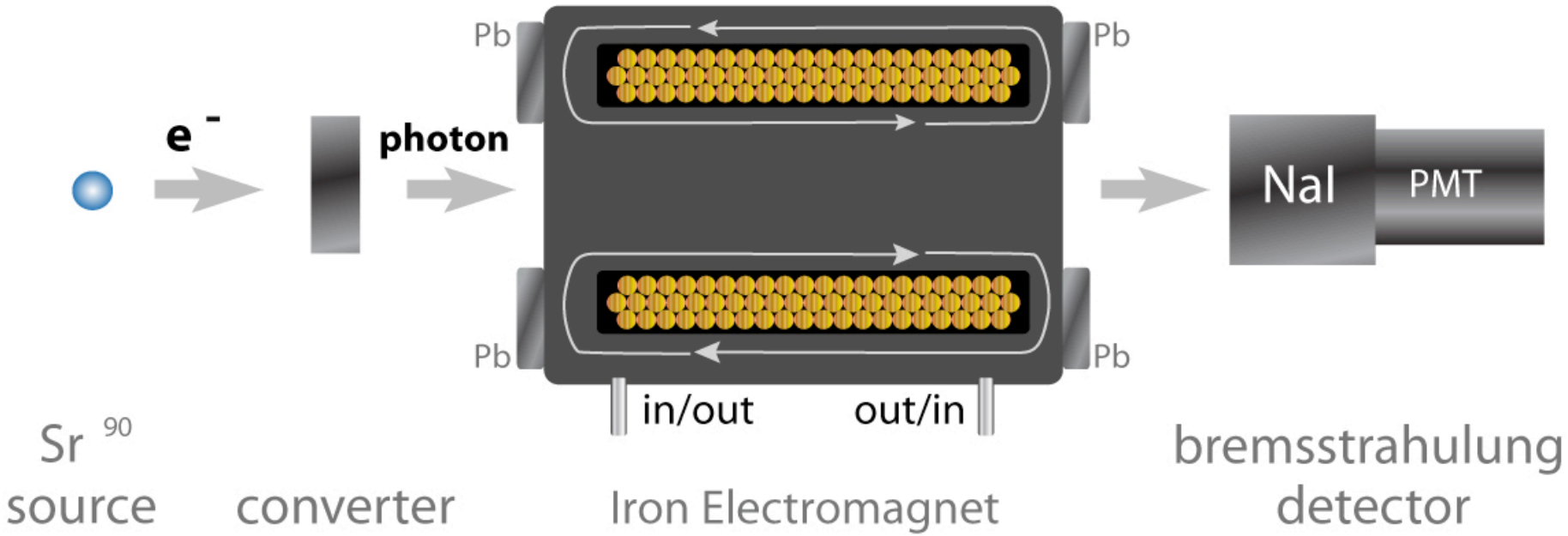
Maurice invokes the conservation of spin
to measure the parity violation
in bremsstrahlung production by β rays.

Bremsstrahlung

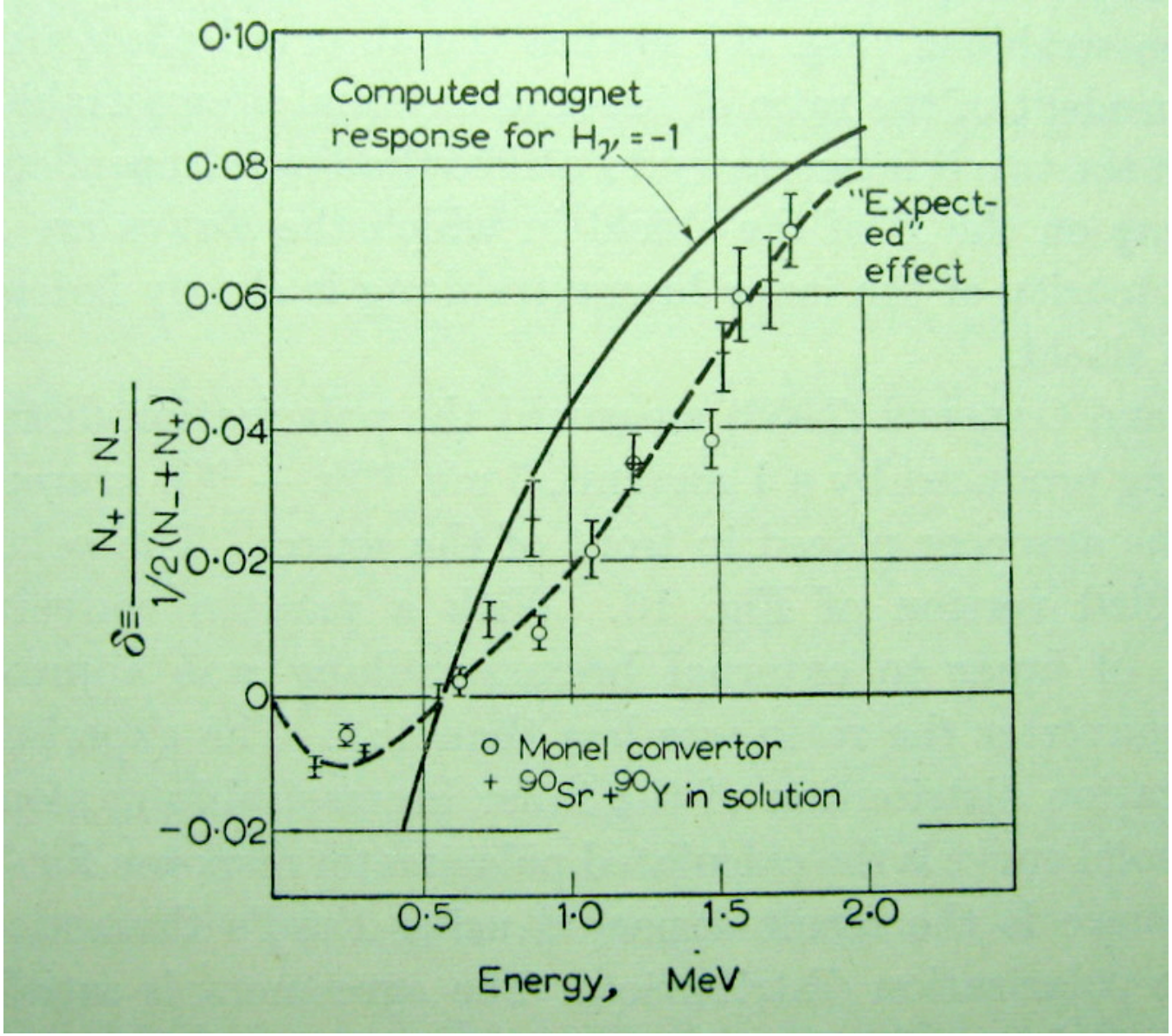


Conservation of Spin



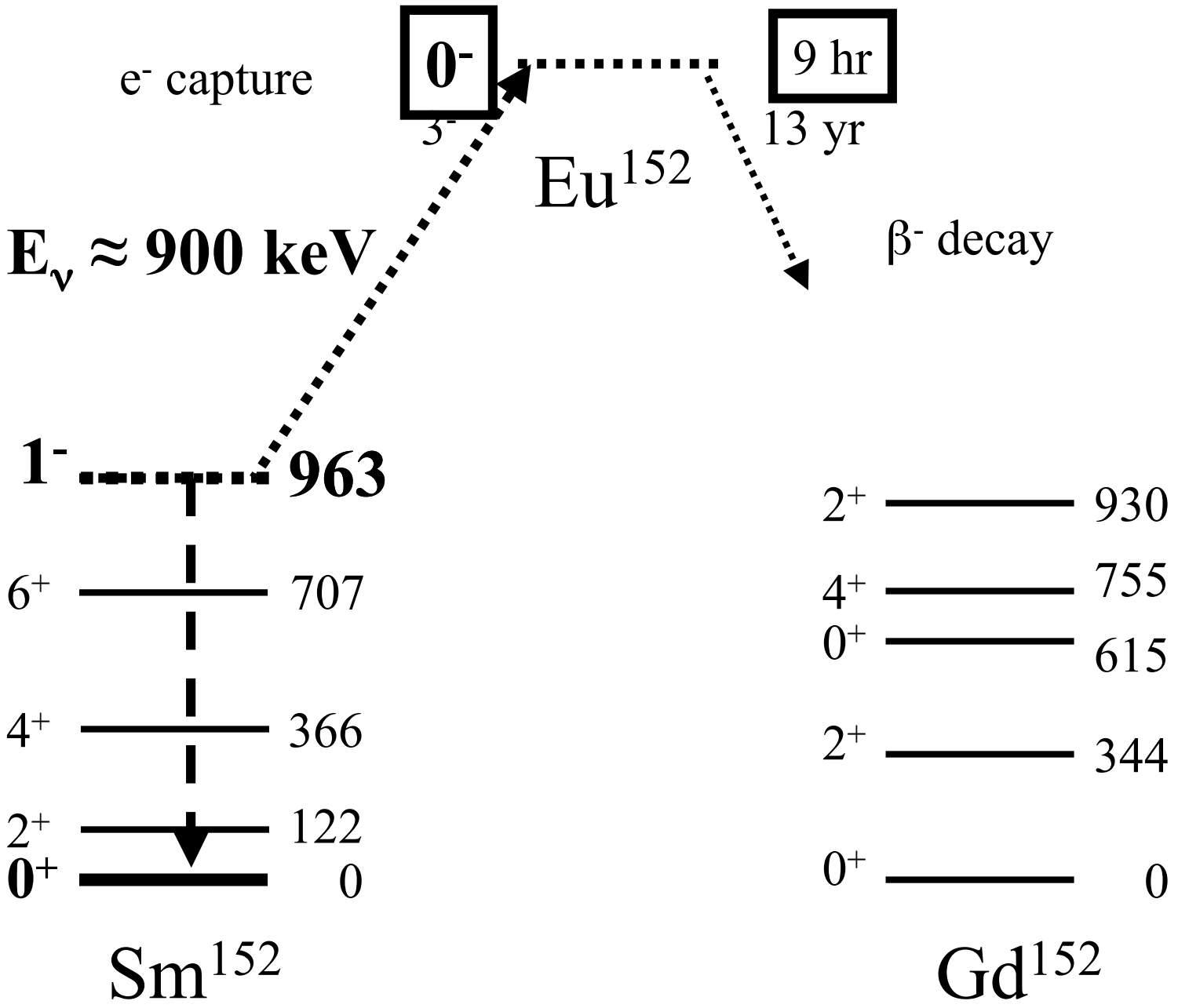

e -
photon
Pb
Pb
Pb
Pb
in/out
out/in
NaI
PMT
Sr 90
source
converter
Iron Electromagnet
bremsstrahulung
detector

Results


0·10
0·08
0·06
0·04
0·02
0
−0·02
Computed magnet response for $H_{\gamma'} = -1$
"Expect-ed" effect
$\delta \equiv \frac{N_+ - N_-}{1/2(N_- + N_+)}$
o Monel convertor
+ $^{90}Sr + ^{90}Y$ in solution
0·5
1·0
1·5
2·0
Energy, MeV

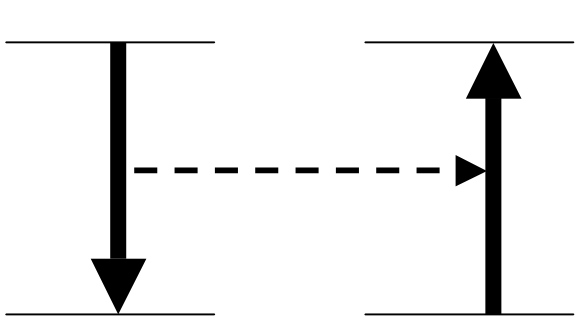
L.G. continues the study of the nuclear spectroscopy of the 88-90 neutron problem.

The measurement of the lifetime of the 1^- level of Sm^{152}.


e- capture
0-
3-
9 hr
13 yr
Eu152
β- decay
Eν ≈ 900 keV
1-
963
6+
707
4+
366
2+
122
0+
0
Sm152
2+
930
4+
755
0+
615
2+
344
0+
0
Gd152

The Fluorescence Requirement

Line Width: ~ .05 eV

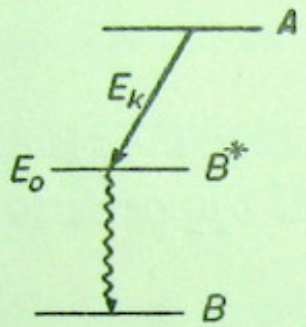


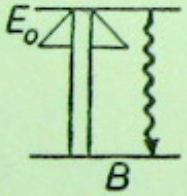
Recoil Loss $\frac{E^2}{2Mc^2}$ **~ 3 eV ~ 3 eV = ~ 6 eV**

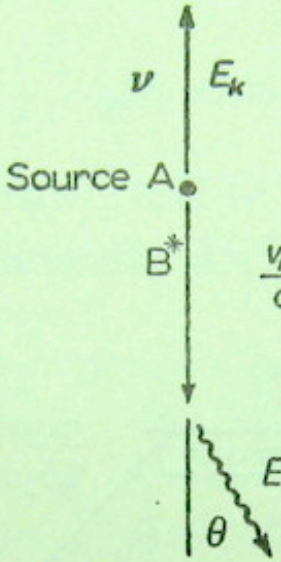
Gain From Neutrino Recoil : ~ 5.4 eV

Temp Broadening: ~ 1 eV

Energy considerations for resonance scattering (K-capture)







$$\frac{v_r}{c} = \frac{E_k}{mc^2}$$

$$E_\gamma = E_o\left(1 + \frac{E_k}{mc^2}\cos\theta\right) - \frac{E_o^2}{2mc^2}$$

Energy available for excitation

Scatterer B •

$$E'_\gamma = E_o\left(1 + \frac{E_k}{mc^2}\cos\theta\right) - \frac{E_o^2}{mc^2}$$

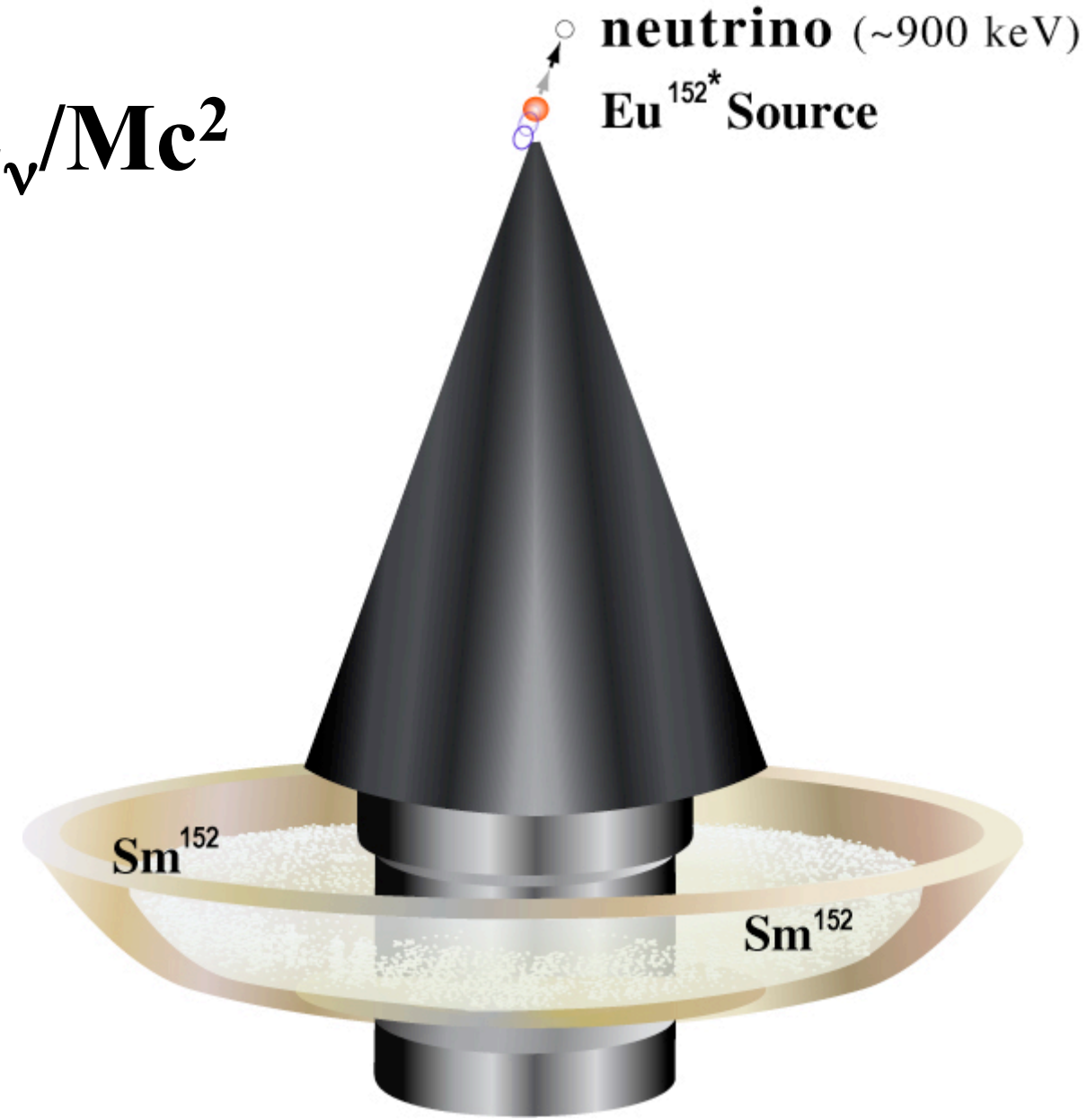
Resonance condition

$$E'_\gamma = E_o$$

$$\therefore\ E_k \cos\theta = E_o$$

Resonance Fluorescence

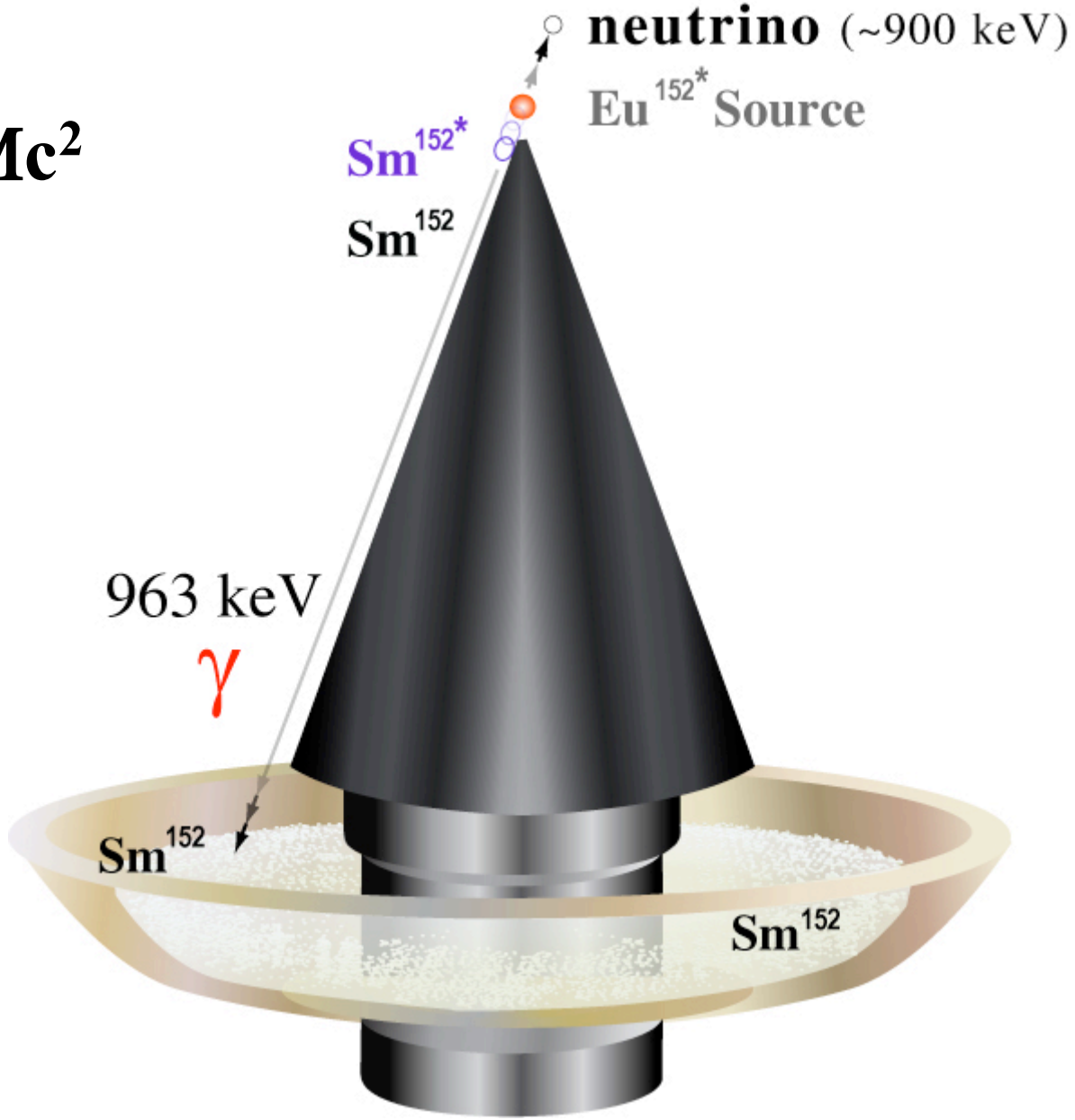
$$v/c)_{recoil} = E_\nu/Mc^2$$



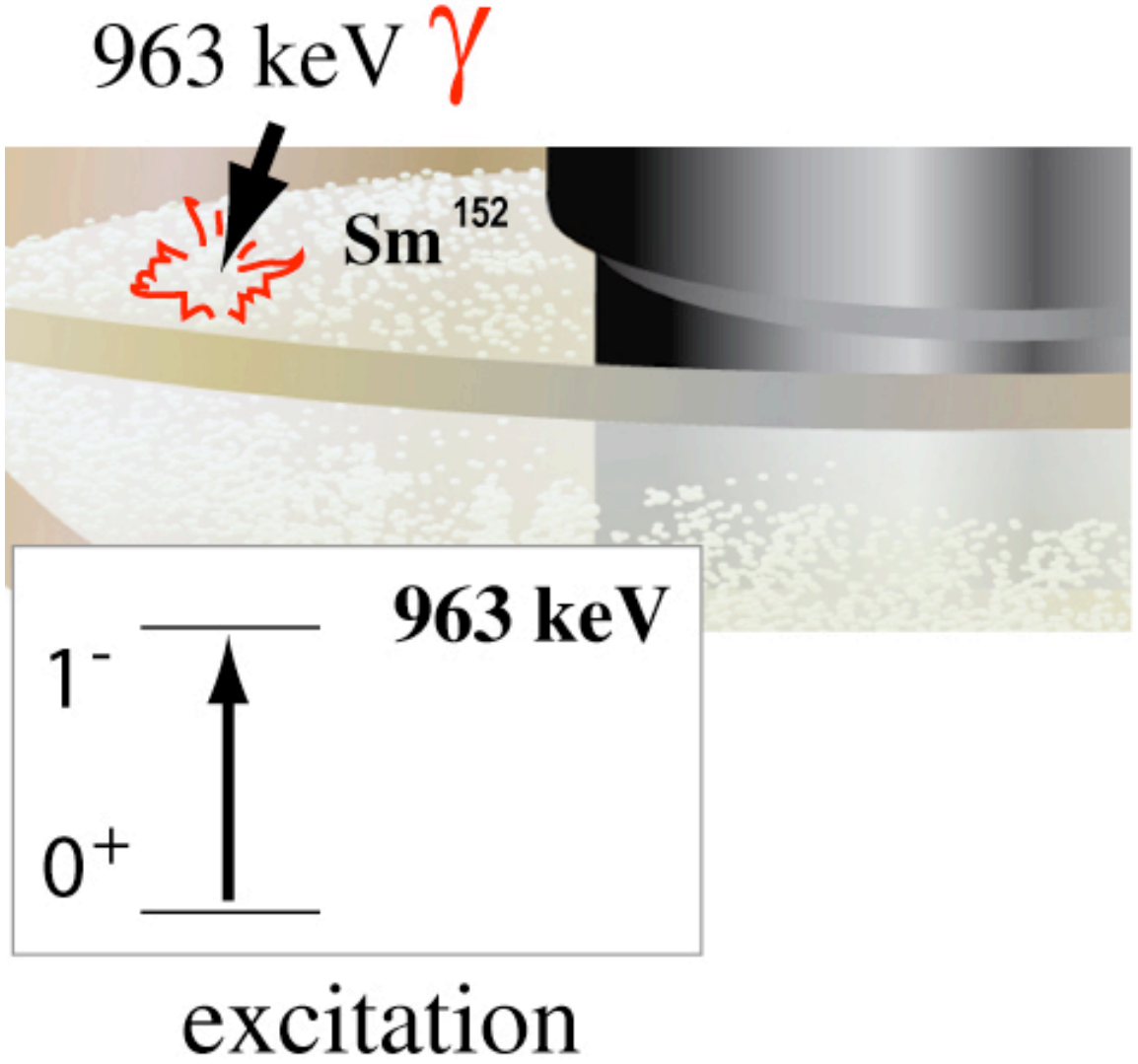
Resonance Fluorescence

γ-ray gains
v/c Eγ = E^2/Mc^2
by Doppler

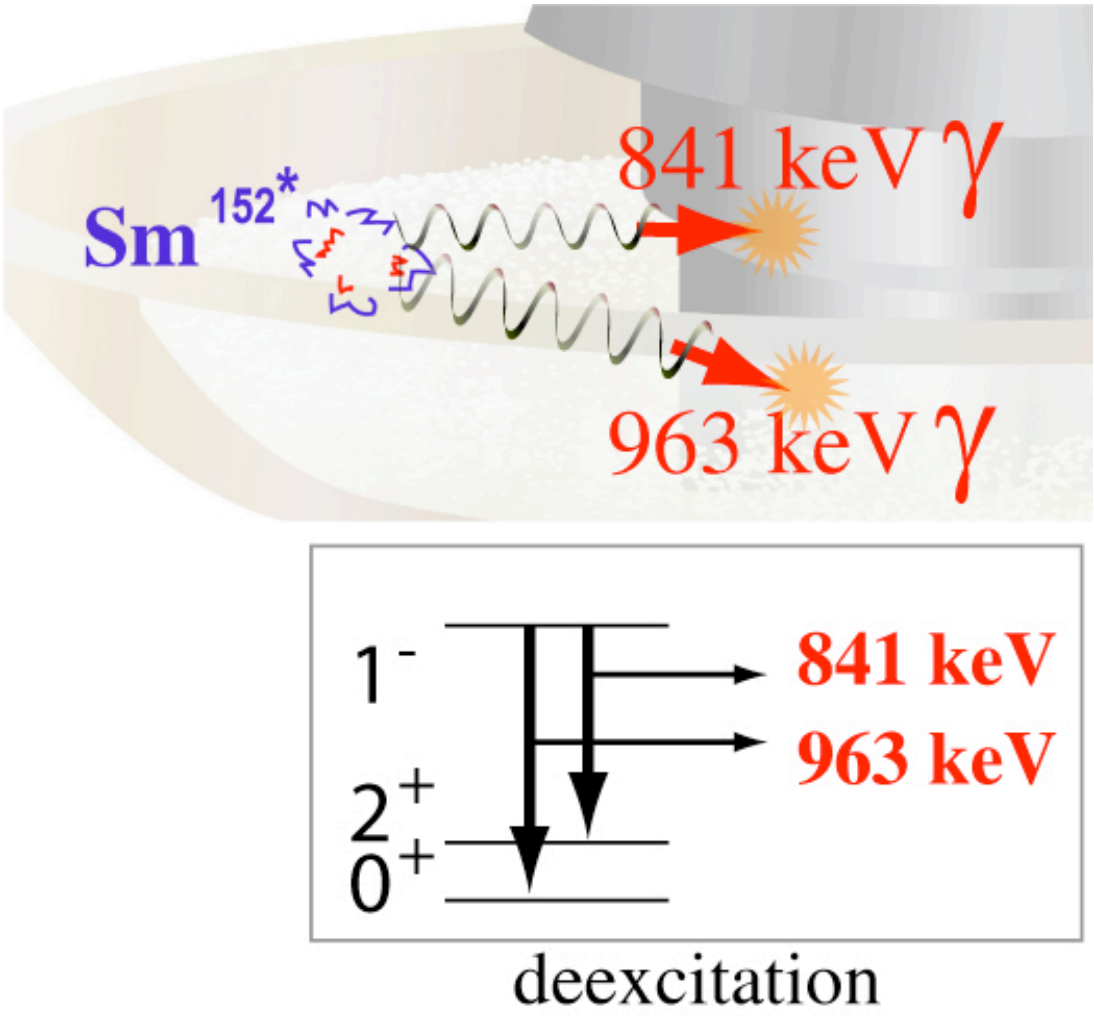
and loses
$E^2/2Mc^2$
by recoil



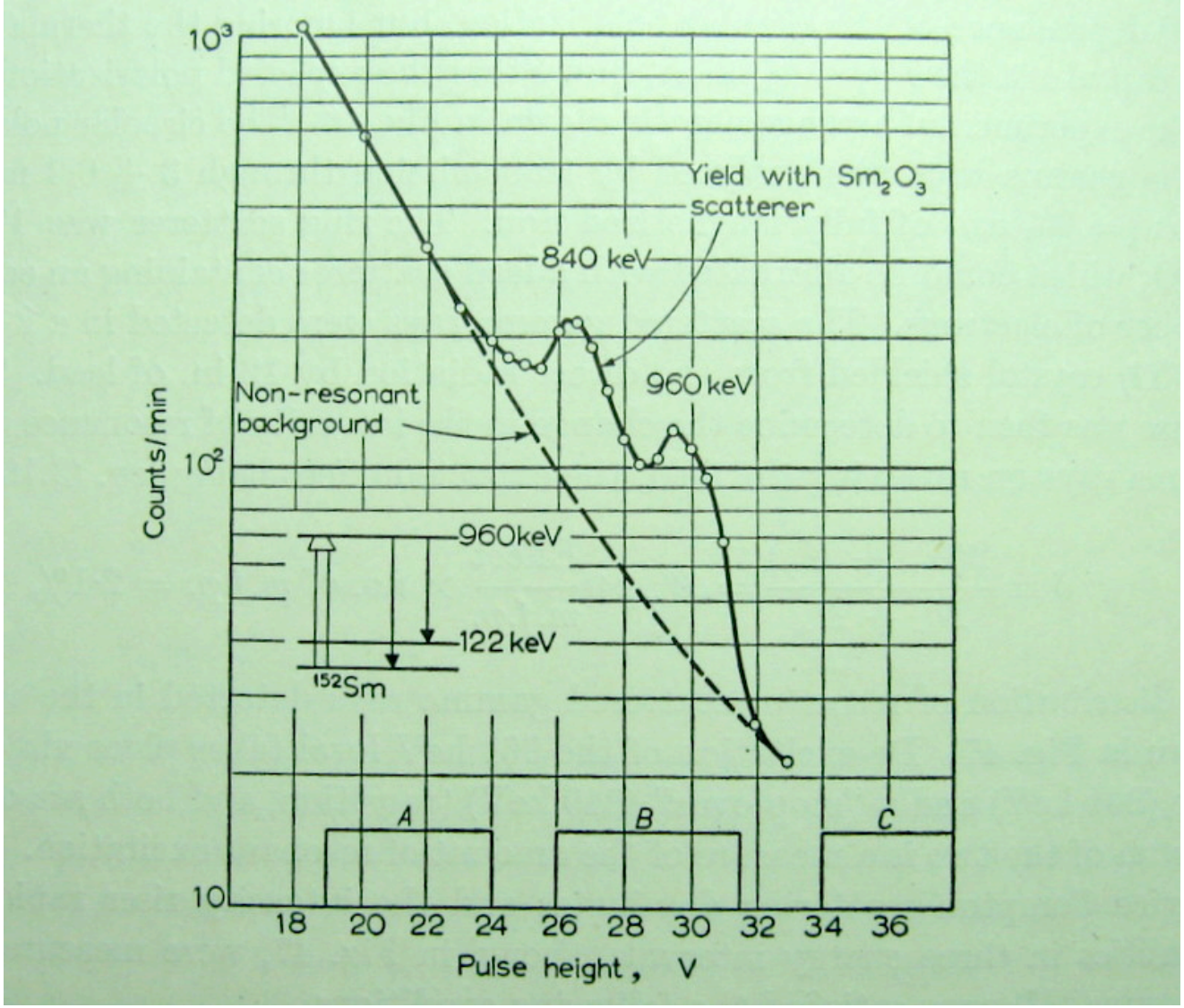
Resonance Fluorescence of the 963 keV State



Deexcitation to the 0+ ground state and 2+ excited state.



The Resonance Signature



Fall, 1957

- **Maurice and Trudy return by boat from Europe.**

- **Maurice calls me into his office and explains how to measure the helicity of the neutrino using the accumulated expertise of the past 18 months.**

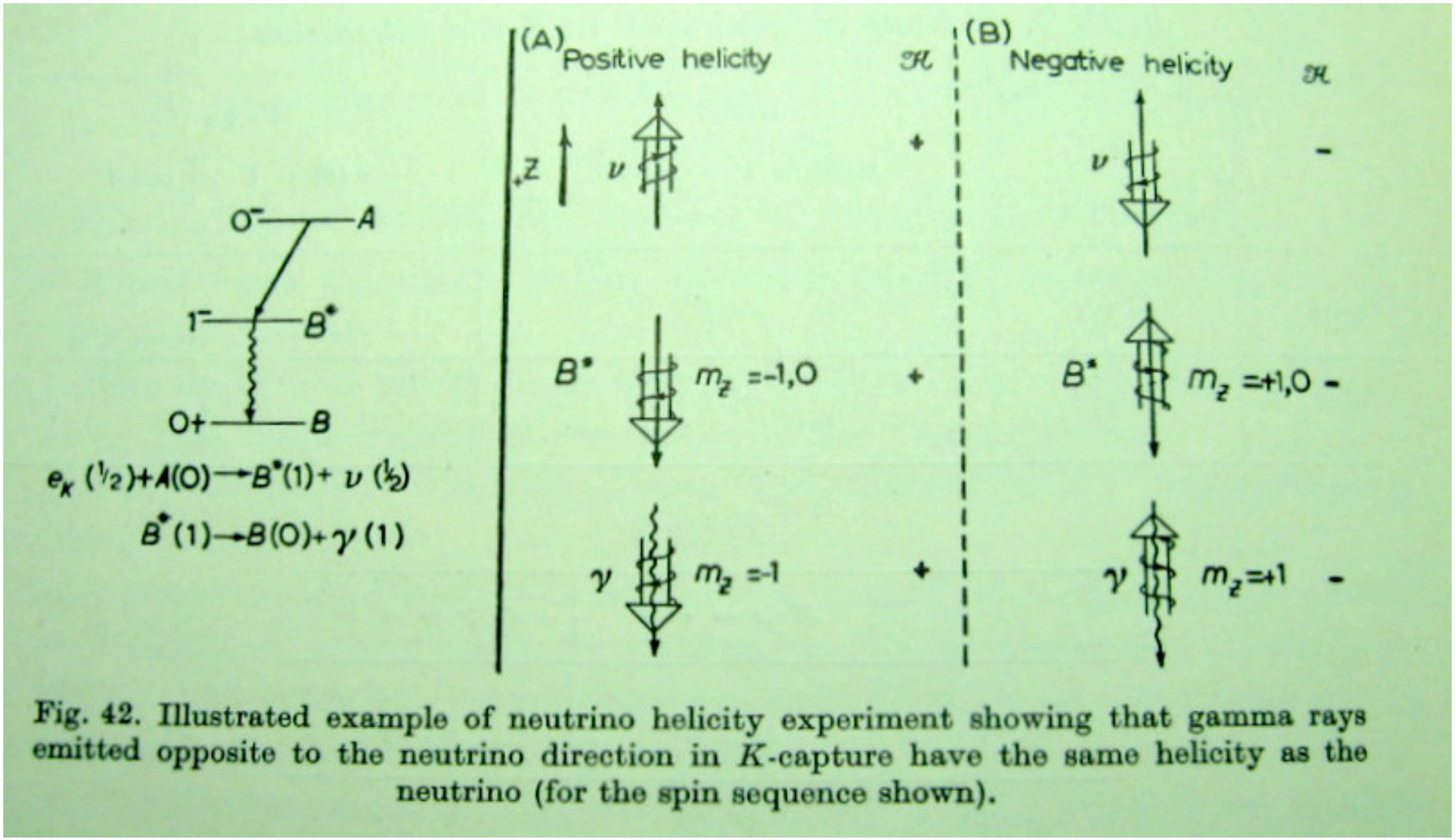
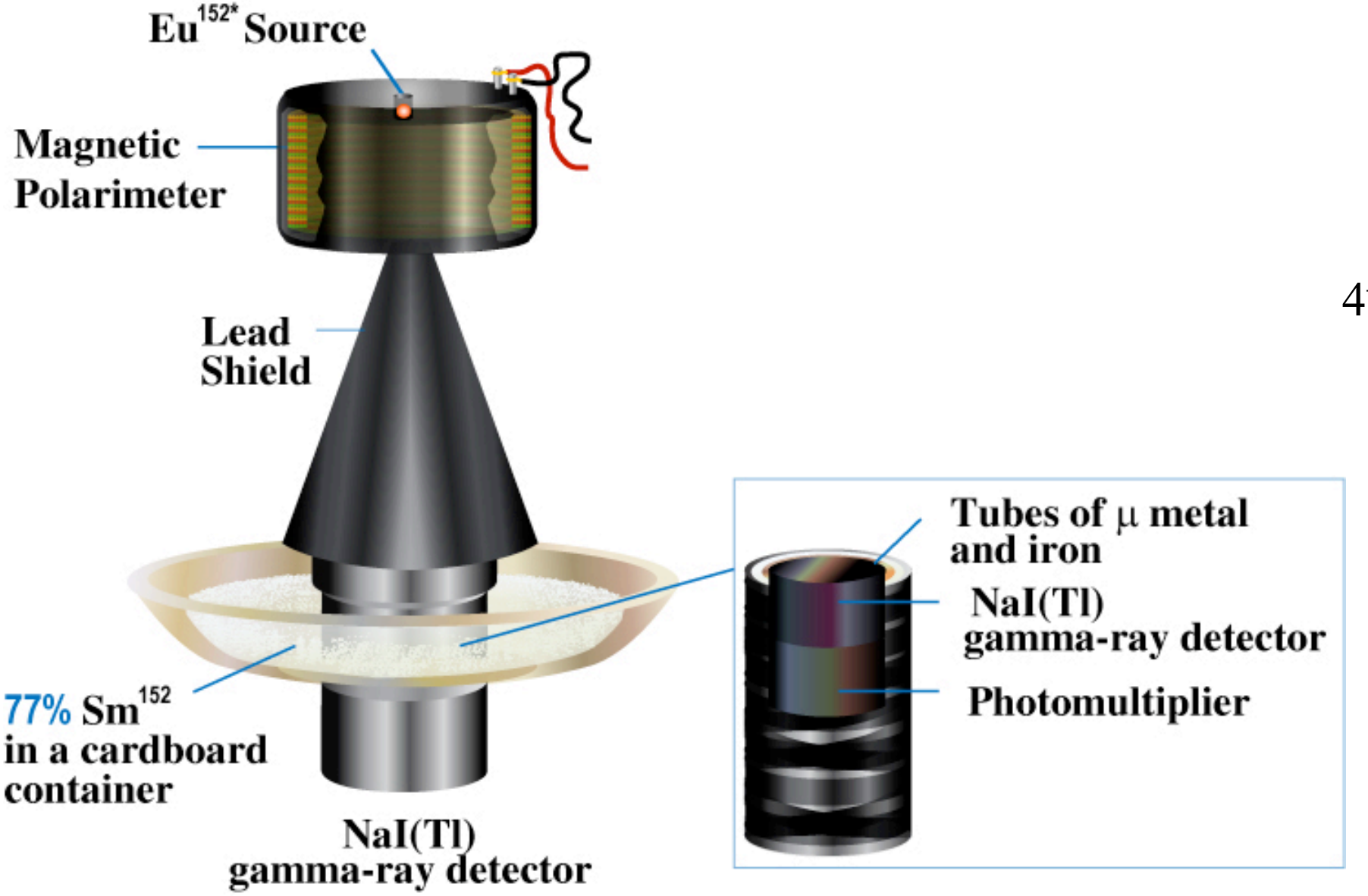


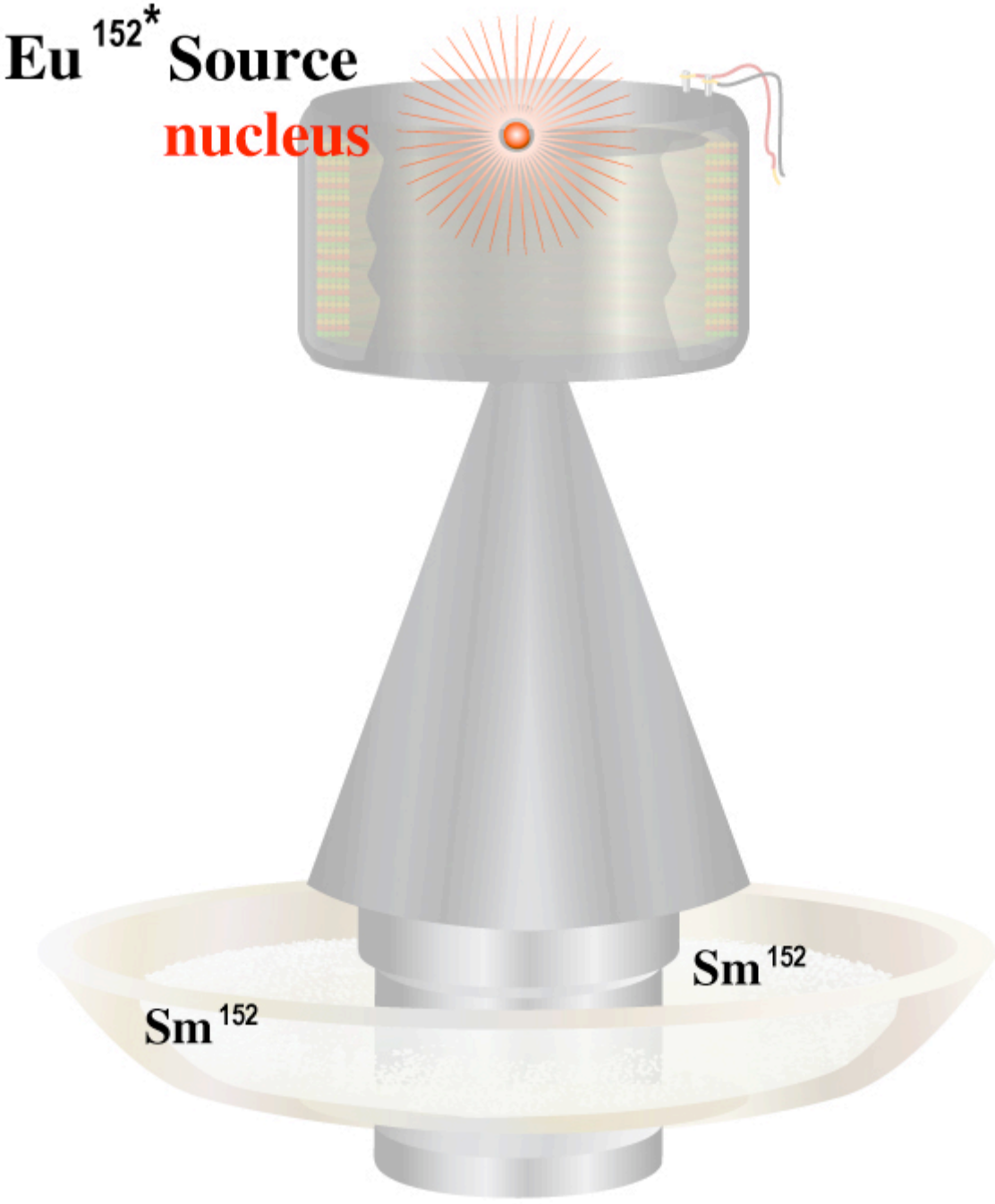
Fig. 42. Illustrated example of neutrino helicity experiment showing that gamma rays emitted opposite to the neutrino direction in K-capture have the same helicity as the neutrino (for the spin sequence shown).

The Helicity Experiment Set-Up



4^{+}

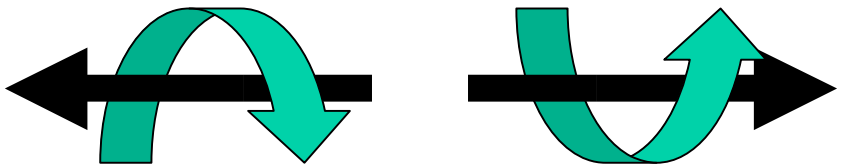
The 9 hr source is placed in a hole drilled in the top of the polarimeter.



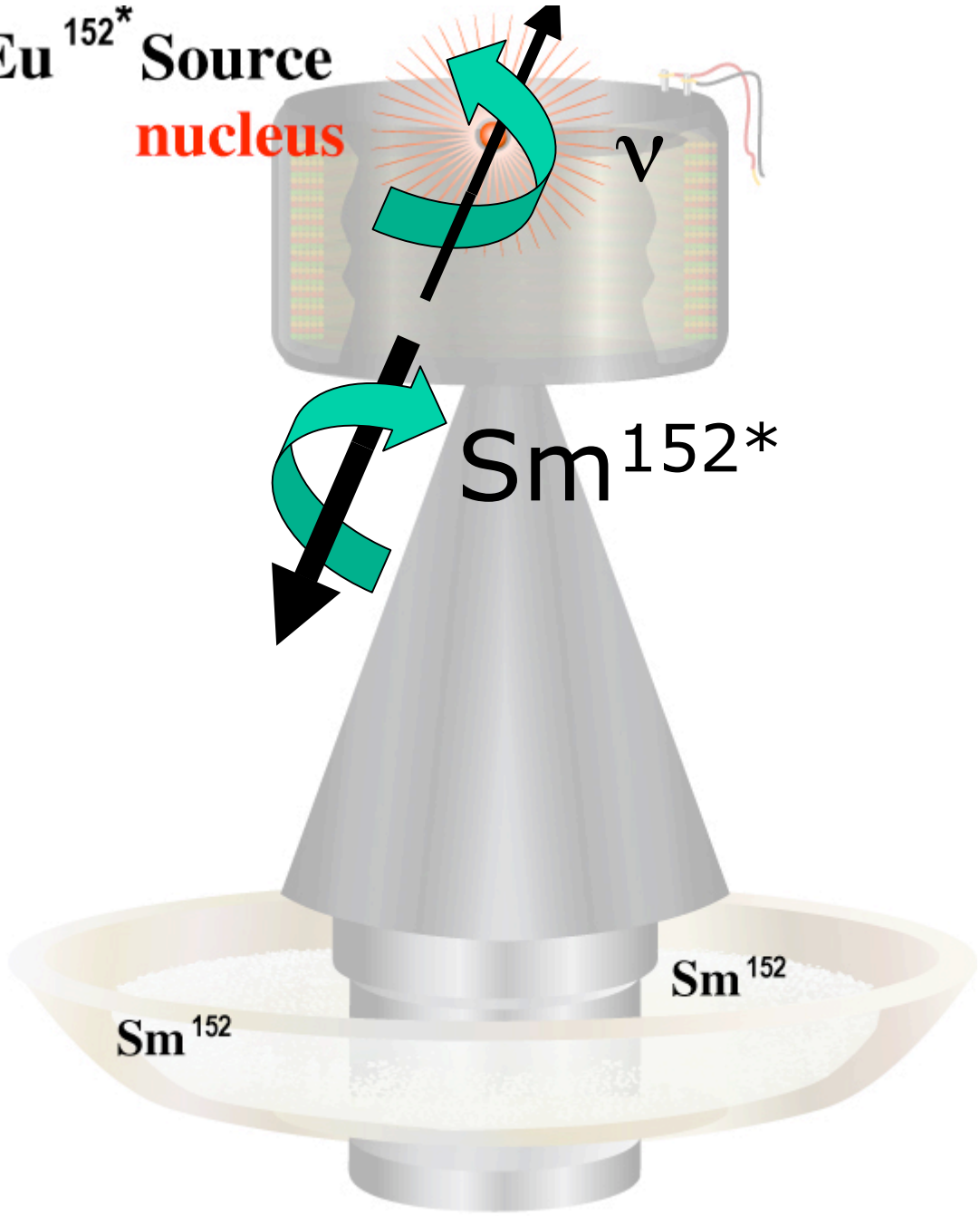
Step 1

$$Eu^{152*} + e_K = \nu + Sm^{152*}$$

$$0 + \_ = \_ + 1$$



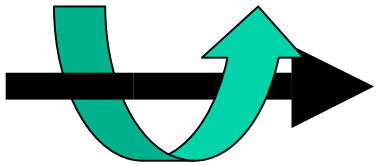
The helicity of the ν is transferred to the helicity of the recoiling Sm^{152*} .

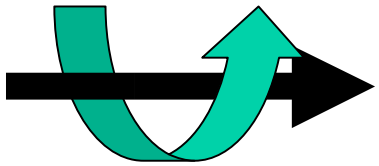


Step 2

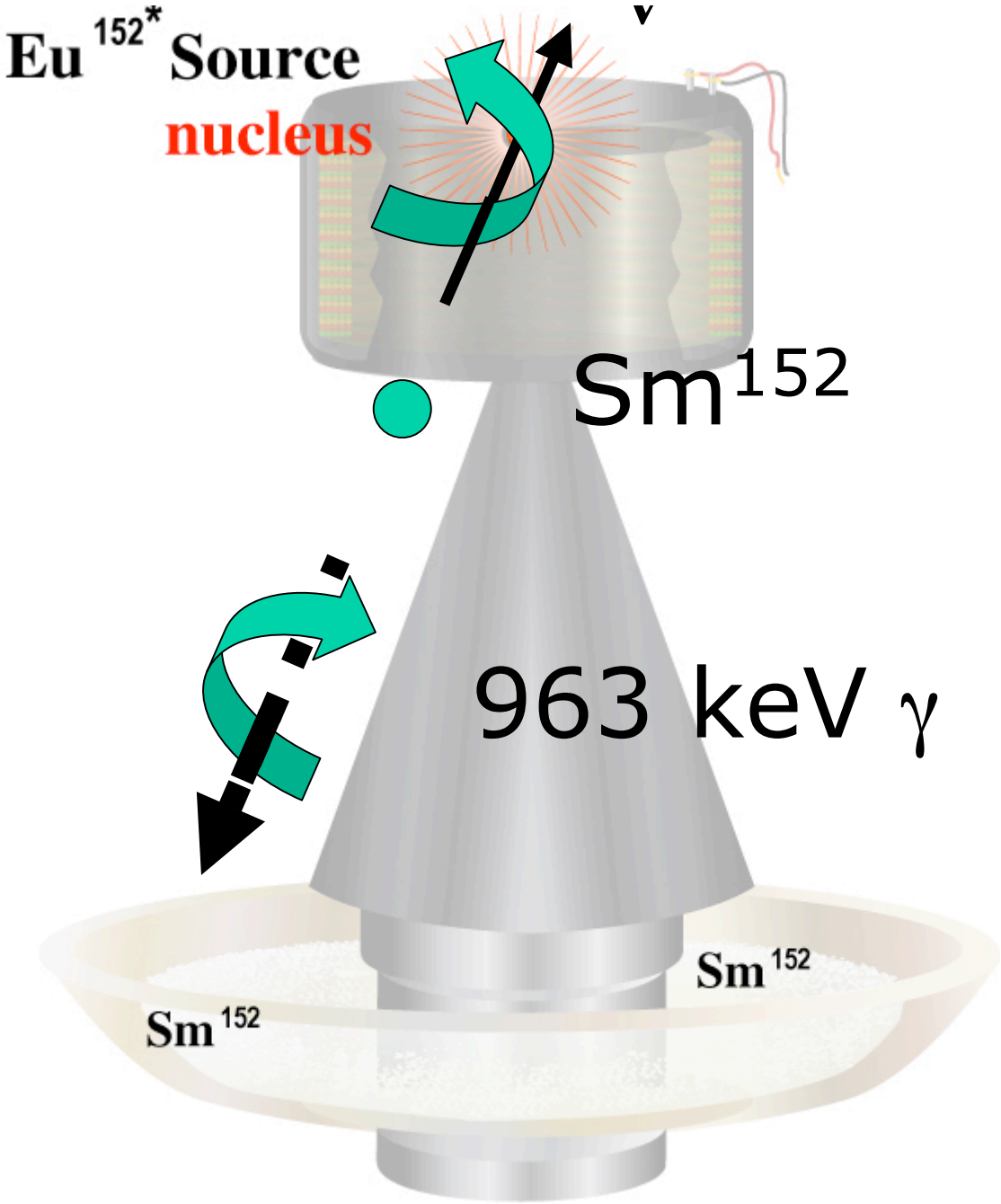
$$Sm^{152*} = Sm^{152} + 963\ \gamma$$

$$1 = 0 + 1$$





The helicity of the Sm^{152*} is transferred to the helicity of the 963 keV γ



The γs

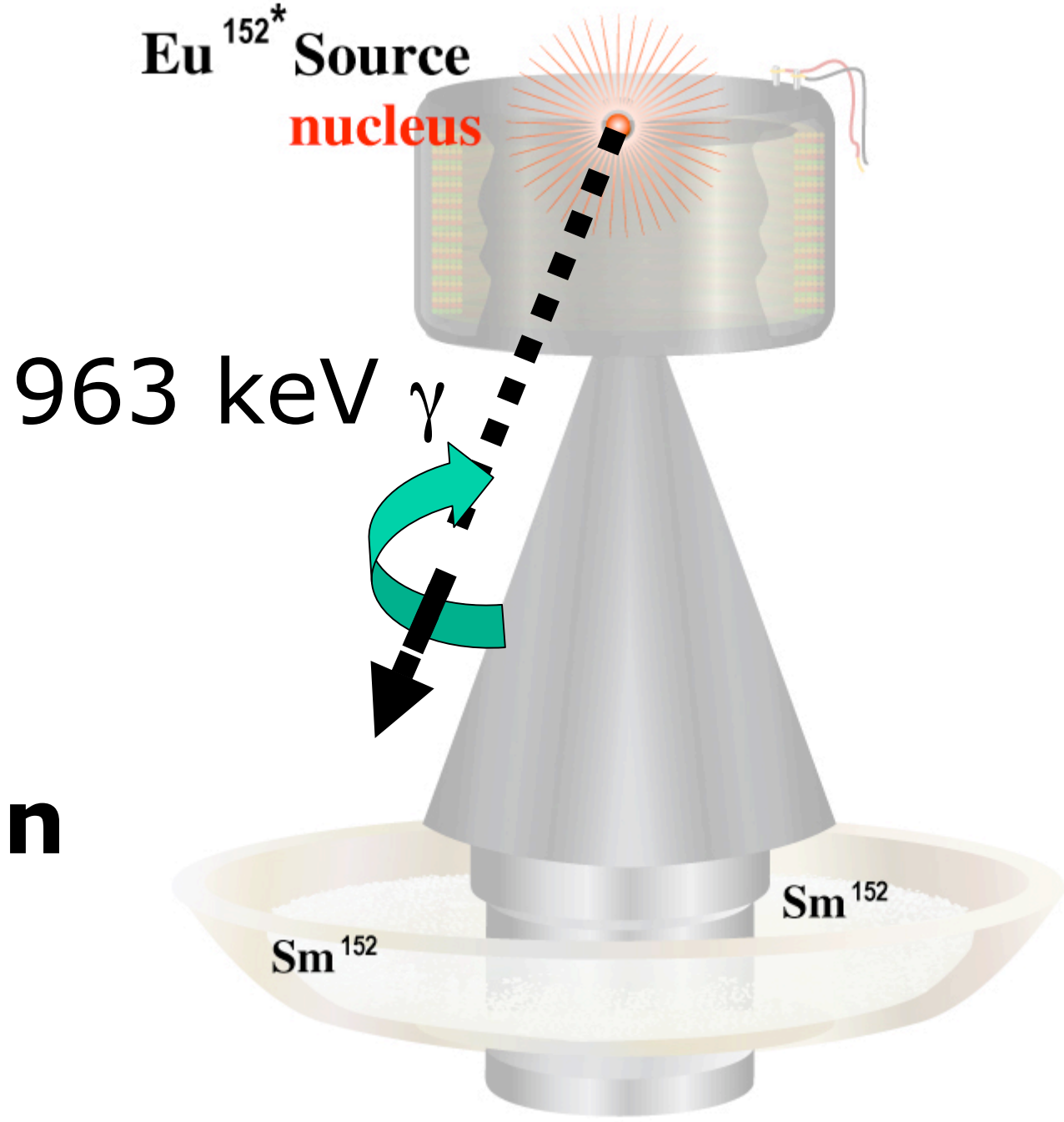
Traverse

About

3 mfps

Of total

absorption

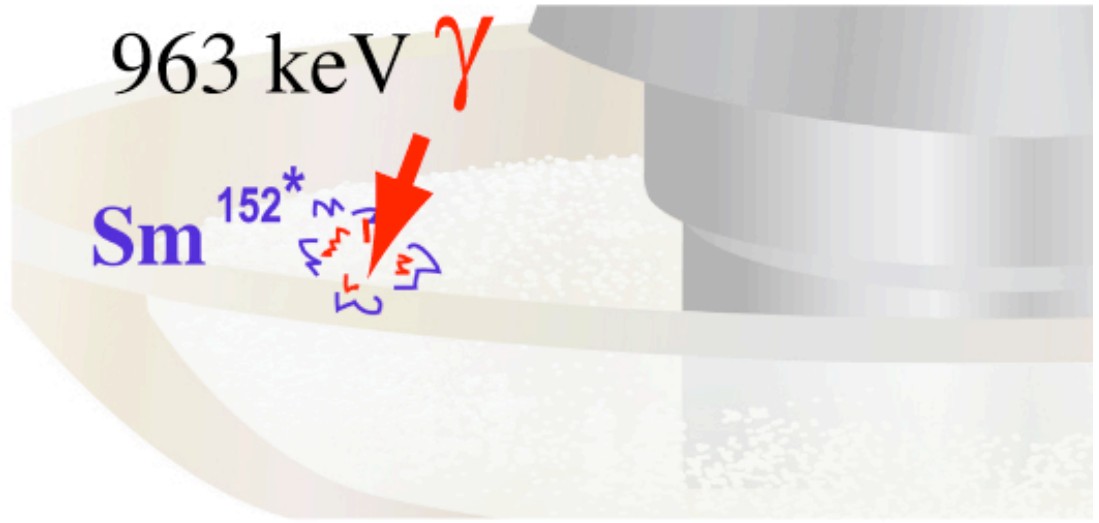


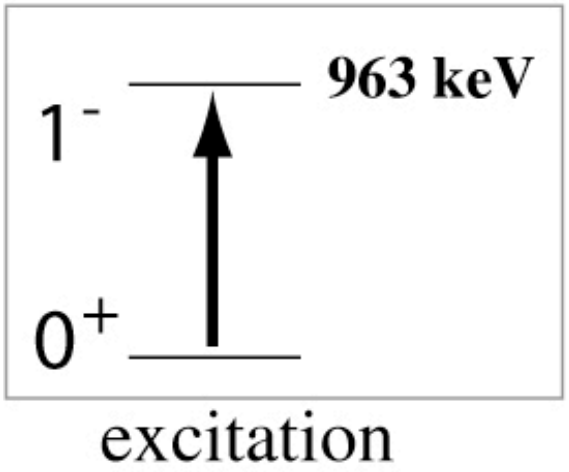
Step 3

$$963\ \gamma + Sm^{152} = Sm^{152*}$$

$$1 \quad + \quad 0 \quad = \quad 1$$

The resonant fluorescence defines the momentum direction of the neutrino.

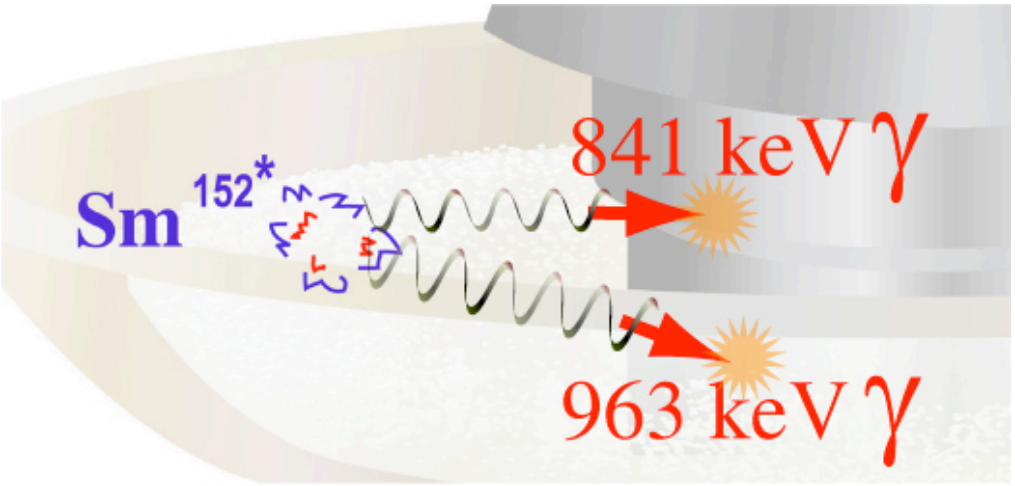




Step 4

$$Sm^{152*} = Sm^{152} + 963\ keV$$
$$841\ keV$$

The deexcitation gammas are measured as a function of the magnetic field direction to determine the helicity of the fluorescing 963 keV gamma.



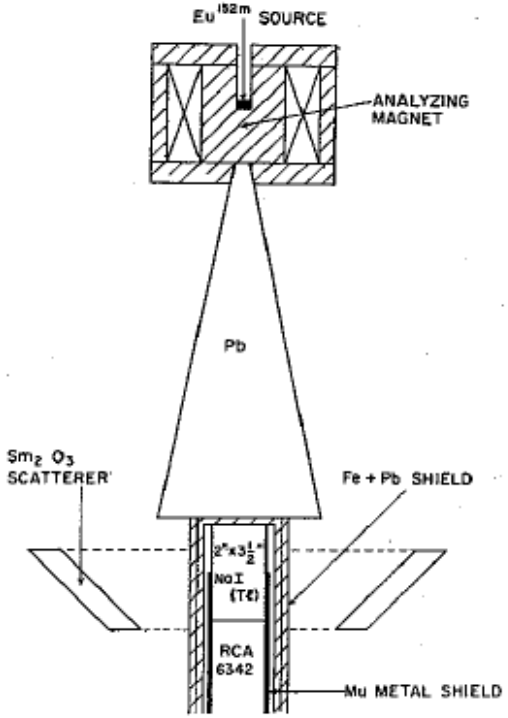


Fig. 6. Schematical arrangement of neutrino helicity experiment. (From Goldhaber *et al.*[1])

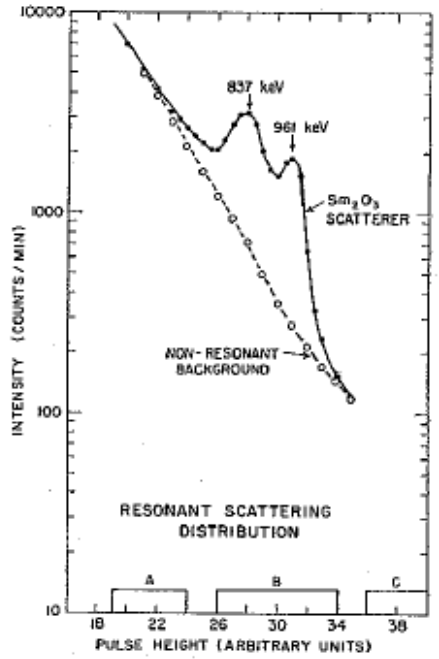
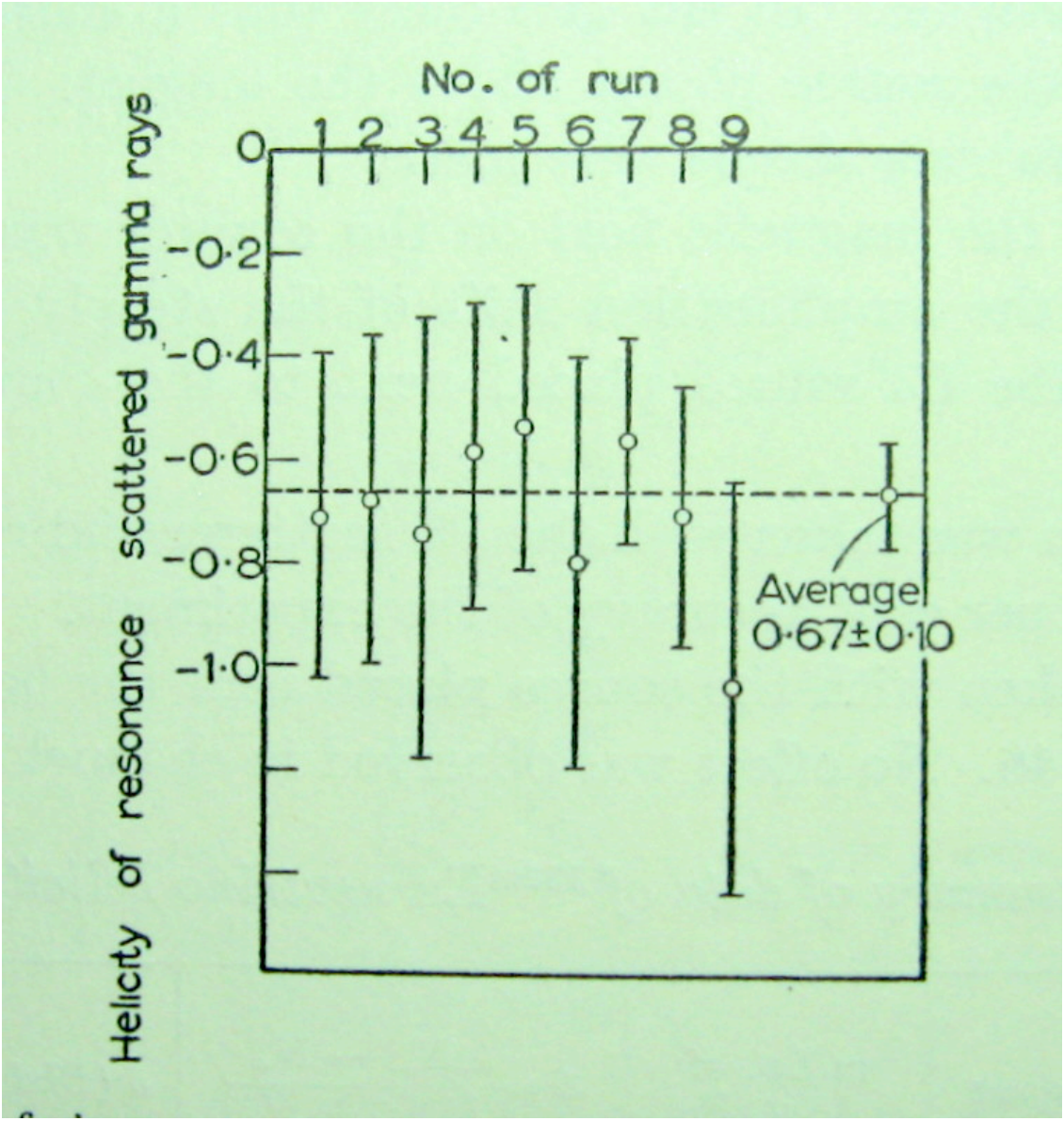


Fig. 7. Distribution of resonant scattered γ-rays of ^{152m}Eu. Taken with arrangement shown in Fig. 6. (From Goldhaber *et al.*[1])


No. of run
0 1 2 3 4 5 6 7 8 9
0
-0·2
-0·4
-0·6
-0·8
-1·0
Helicity of resonance scattered gamma rays
Average
0·67±0·10

- **No pictures have been found of**
- **Maurice with the apparatus**
- **or**
- **Maurice, Andy and I with the apparatus.**
- **The only relevant picture that I know of was taken by a photographer for the New York Daily News for a feature article in the Sunday paper**
- **Written by the Jazz Critic.**

Science non-fiction

Sunday New, September 21, 1958

Happy Birthday[97]

Maurice